



Impact of Coal Mining in Forest Area to Carbon Emission in Kutai Kartanegara, East Kalimantan

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Abstract: *Coal mining is an activity that contribute to greenhouse gas emissions, both from methane gas release of coal trap and the loss of land cover plants. This study was conducted to estimate carbon emissions in coal mining areas inside forest areas by analyzing changes in landcover. The area of this study is Kutai Kartanegara Regency, East Kalimantan, where coal mining activities are quite massive. To obtain the extent of changes in land cover and the amount of carbon emissions in the area, analysis of Landsat 5 TM and Landsat 7 ETM+ imagery in 2010 and also the 2016 Landsat 8 OLI/TIRS imagery was used. The results showed that in the area of study there was a change in landcover of 12,663.28 Ha in the forest areas used for coal mining activities. Carbon emissions generated from this activity amounted to 0.60 Mton CO₂-Eq.*

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INTRODUCTION

During the past 25 years, around 82% of the world's primary energy needs is coming from fossil energy, including coal (National Energy Council, 2014). Then, over the past 10 years, coal needs in Indonesia have risen sharply along with the addition of coal-fired steam power plants. This was also followed by the expansion of coal mining, especially in the Kalimantan region. Coal mining is one of the activities which drive economic growth in Indonesia and become a lever of local economic activities.

In Indonesia, forestry activities are still seen as a supporting sector to national and local economies, while its benefit on providing ecosystem protection, especially the provision of water and oxygen. Handoyo and Cicilia (2014), said that about USD 8.9 million total of forest product were exported from Indonesia to many countries, based on Ministry of Trading and Industry Therefore, those both sectors have prominent influence towards the economic growth and must be able to go concomitant.

However, in fact a lot of coal mining activities take place in forest areas. Coal mining activities in East Kalimantan are partly located in forest areas. Su-hanto (2012) stated that 10% of the coal mines in are located in forest area.

Coal mining is an open-pit mining and consequent-ly, turns vegetated land into non-vegetated one. Coal mining consession in the forest area, then called forest use consession, causes carbon emission from the LU-LUCF (Land Use, Land Use Change and Forestry) sector. Sonya (2012) mentioned that LULUCF were responsible for 55 to 79% of the green house emission.

Carbon emission which caused by LULUCF need land cover change monitoring from two different time using remote sensing satellite. Olofsson et al. (2010); Ferreira et al. (2011); Goetz and Dubayah (2011); Margono et al. (2012); and Sonter et al. (2013) conducted previous studies that observed forest resources monitoring using satellite imaging for analyzing the change of landcover in forest area. Furthermore, Munawar et al. (2015) explained satellite observation can be used for identifying deforestation and forest degradation and increasing carbon emission.

In study Abood et al. (2015), had revealed that 44.7% (± 6.6 million hectares) of forest loss in Indonesia between 2000 and 2010, resulting in 4,577 to 8,662 million tons of CO₂ in the concession areas. Therefore, we researched further studies on how much carbon emission from land cover changes in concession area, which is forest areas used concession for coal mining activity. The objective of the study is to estimate carbon emission that caused by landcover change inside forest areas in in Kutai Kartanegara, East Kalimantan due to coal mining activity.

METHOD

Area of Study

The area of study is Kutai Kartanegara Regency, East Kalimantan Province. Kutai Kartanegara is located in 115°26'28" - 117°36'43" longitude and 1°28'21" - 1°08'06" latitude which has total area about 27 263.10 km². Its topography is bumpy to hilly with steep slope in which height is between 500-2,000 meters above sea level. It has humid tropical forest climate and different climate between hot and rainy season is subtle. Rainfall is between 2 000 and 4 000 mmy-1 and average temperature is 26 °C.



Figure 1 Area of study Regency.
(Source: <http://kabupaten.kutaiartanegara.com>)

Kutai Kartanegara is famous for their forest and energy resources, such as coal, oil and gas. Their forest commodity consists of wood commodities like Jabon (*Neolamarckia cadamba*), Kaliandra (*Calliandra sp.*), and Sengon (*Albizia chinensis*), and non-wood commodities, which are rattan (*Calamus sp.*), "gaharu", aromatic products, honey, "matoa", fruit, and "jelutung", resin. Mining has a vital role towards Kutai

Kartanegara economics. Both oil and gas as well as non-oil and gas resources are their primary export commodities. The total coal production in 2015 was 55 844 597.90 tons (from 73 coal mines).

In 2006, Kutai Kartanegara was dominated by forest consisting of shrubs, dense forest, swamp forest and forest used for industrial plantation; the total forest area in 2006 was 1 858 237 Ha (68.16% of the total size of the municipality). 160 369 Ha are used for residential area; 53 437 Ha is used for ricefield; 183 807 Ha is for dry farm/moor; 70 523 Ha is for lake, swamp, fish farm and rivers, and the remaining 433 346 Ha consists of shrubs, reeds, shifting cultivation and excavation.

Time of Study

This study was held from February 2017 to February 2018. A year of study used to collecting and analyzing data. Most of time was used for interpreting Landsat Imagery.

Materials

All the data is secondary which obtained from many sources, such as literatures, internet, free satellite images, and thematic map. Satellite images used in this study are Landsat 5 TM, Landsat 7 ETM+ and Landsat 8 OLI/TIRS. Data on the 2010 landcover were obtained from the Landsat 5 TM and Landsat 7 ETM+ image interpretation, while the Landsat 8 OLI/TIRS images were used for the 2016 landcover identification (Table 1). These data is downloaded from <https://earthexplorer.usgs.gov/>.

This research also used SNI 7645: 2010 on the Landcover Classification and the 2015 Regulation of the Director General of Forestry Planology and Environmental on Guidelines for Forest Resources Monitoring for key of interpretation. Then, for reference of ground control point is using image of google earth. To narrow the area study that focused on forest use concession, digital map of forest use concession distribution of Kutai Kartanegara is being used. The source of this data is Directorate General of Forestry Planology and Environmental.

Table 1 Landsat Imagery used in the Study.

No	Type of Image	Path/Row	Recording Time
1	Landsat 5 TM	116/061	May 19, 2010
2		116/060	January 27, 2010
3			May 3, 2010
4		117/060	December 30, 2010
5	Landsat 7 ETM+	117/060	February 11, 2010
6			December 12, 2010
7	Landsat 8 OLI/TIRS	116/061	February 13, 2016
8			August 7, 2016
9		116/060	January 28, 2016
10			February 20, 2016
11		117/060	March 7, 2016
12			April 8, 2016

Source: USGS earth explorer, 2016

Analysis Methods

Pre-image Processing

Geometric correction was conducted on the Landsat 5 TM taken on May 19, 2010 using the Landsat 8 OLI/TIRS taken on August 7, 2016 as the reference. Pre-image processing was also conducted on the Landsat 7 ETM+ image because SLC off caused stripping on the image. This process called “gapfill” which required

one or more image scenes on the same path/row taken in different time. An image scene was used as basic image and another one was used as filling image. low Cloud closure level became the basis for basic image and filling image selection. The basic image was selected from scene of which cloud closure image was low on certain interpreted areas.

After gapfill has been completed, the landsat images were cut into several smaller pieces based on the concession areas and interpreted using 543 band combination band for Landsat 5 TM and Landsat 7 ETM + and 654 band combination for Landsat 8 OLI / TIRS. These combinations were selected based on the SNI 7645: 2010 on the Landcover Classification and the 2015 Regulation of the Director General of Forestry Planology and Environmental on Guidelines for Forest Resources Monitoring. The band combinations display a clear contrast between vegetated and non vegetated land.

Image classification

Based on the composite image, supervised classification was conducted using the maximum likelihood approach. The training area was determined based on the landcover maps and control points from the Google Earth image (map to map reference). There 488 reference points collected from Google Earth for 2010 and 488 reference points for 2016; the number was varied each scene. The reference points were the reference for creating a sample for the supervised classification.

Landcover Change Analysis

Post-classification comparison change detection, of which basis was classified raster data vectorization, was the method used to identify landcover change. Remote sensing technique can detect changes in the Earth's surface. While detecting, multitemporal data application for quantitative analysis should be implemented in order to analyze these changes from time to time.

Carbon Emissions Estimation

Different amount of carbon stock, from one landcover to another, was the type of information used to identify estimated amount of carbon emission (IPCC, 2006). Type of carbon emission analyzed in this study was carbon emission equivalent (CO₂-eq), with conversion factor of 44/12 or 3.67 times carbon reserve (C ton/hectare). Its unit of measurement was Mton CO₂-eq. Equation 1 is used to calculate the carbon stock difference.

$$\Delta C = (C_1 - C_0)$$

ΔC is carbon stock difference (C Ton/Hectare); C_0 is carbon stock on preliminary observation (C Ton); and C_1 is carbon stock on final observation (C Ton). Carbon Emission/Absorption is determined by Equation 2.

$$E/A = \Delta C \times L_{LCF} \times 3.67$$

E/A is carbon emission/absorption (Mton CO₂-eq); ΔC is carbon stock difference in different landcover (C Ton/Hectare); L_{LCF} is size of landcover change (Hectare). Thus, Carbon Emission/Absorption is calculated by Equation 3.

$$\text{Nett Emission} = \text{Emission} - \text{Absorption}$$

Nett Emission referred to calculation between emission and its absorption in all landcover types. Emission took place carbon stock changed from high to low (+) while absorption took place when carbon reserve changed from high to low (-).

RESULTS AND DISCUSSION

Landcover Change in the Forest Use for Coal Mining Concession Areas

Based on the 2010 and 2016 Landsat time series data, there was change in landcover pattern in the forested area and non-forested area (Table 2). There were 13 different types of landcover, which are: 1) secondary dry land forest, 2) forest plantation, 3) shrubs, 4) shrubs and swamp, 5) crop estate, 6) dry land farming, 7) dry land farming mixed shrubs, 8) rice field, 9) open area, 10) mining, 11) residential area, 12) water, and 13) swamp.

Table 2 Total Landcover Area for Forest Use for Coal Mining Concession Areas.

No	Landcover Type	Size (Hectare)		Change in Size (Hectare)
		2010	2016	
1	Secondary Dry Land Forest	522.80	517.57	23.51
2	Forest Plantation	7 112.78	5 551.18	2 535.22
3	Shrubsland	31 741.82	28 416.03	6 051.93
4	Shrubsland of Swamp	205.46	208.10	40.35
5	Crop Estate	20.87	45.65	6.69
6	Dry Land Farming	22.31	23.91	4.09
7	Dry Land Farming mixed Shrubs	283.22	739.77	71.02
8	Rice Field	321.11	63.82	283.35
9	Open Area	3 252.95	6 069.87	1 603.24
10	Mining	3 906.26	5 262.91	1 735.03
11	Residential Area	8.27	22.70	
12	Water	639.53	1 115.92	308.86
13	Swamp	0.36	0.36	
Total		48 037.79	48 037.79	12 663.28

Source: Data processing

There was 5.23 Ha decrease in the secondary dry land forest and 1 561.60 Ha in the forest plantation. Size of the shrubs and rice field also declined in 2016. 3 210.42 ha of shrubs turned into open areas and 1 801.20 ha of shrubs turned into mining areas. The remaining became shrubs and swamps, crop estate, dry-land farming, dry-land farming and shrubs, residential areas and water. 45.64% of the rice field turned into shrubs and 26.50% into mining areas. Besides that, the rice field also turned into dry-land farming and shrubs, open area and water.

Size of the mines increased from 3 906.26 into 5 262.91 ha or 2.82% in 2016. In the same year, approximately 12.64% of the open area became coal mining. There was 50% increase of water in the concession land from 639.53 Ha in 2010 into 1 115.92 Ha in 2016.

Sihombing (2013) argued that change in land clearing would result in degrading quality of land in the concession area. The number of non-vegetated area that turned into coal mines was far more than the vegetated area. It showed that forest destruction affect the quality of land in a significant number.

A lot of vegetated land in the concession area turned into coal mines. Instead of being used for coal excavation, the vegetated area supply soil for the coal mines. Excavation also floods the forest turning it into body of water (Yadav and Borana 2017). Samanta (2015) highlighted major change in land clearing. As the result of land clearing, conversion of land into coal mines, 53.95 km² of primary forest and 117.37 km² of secondary one were destroyed.

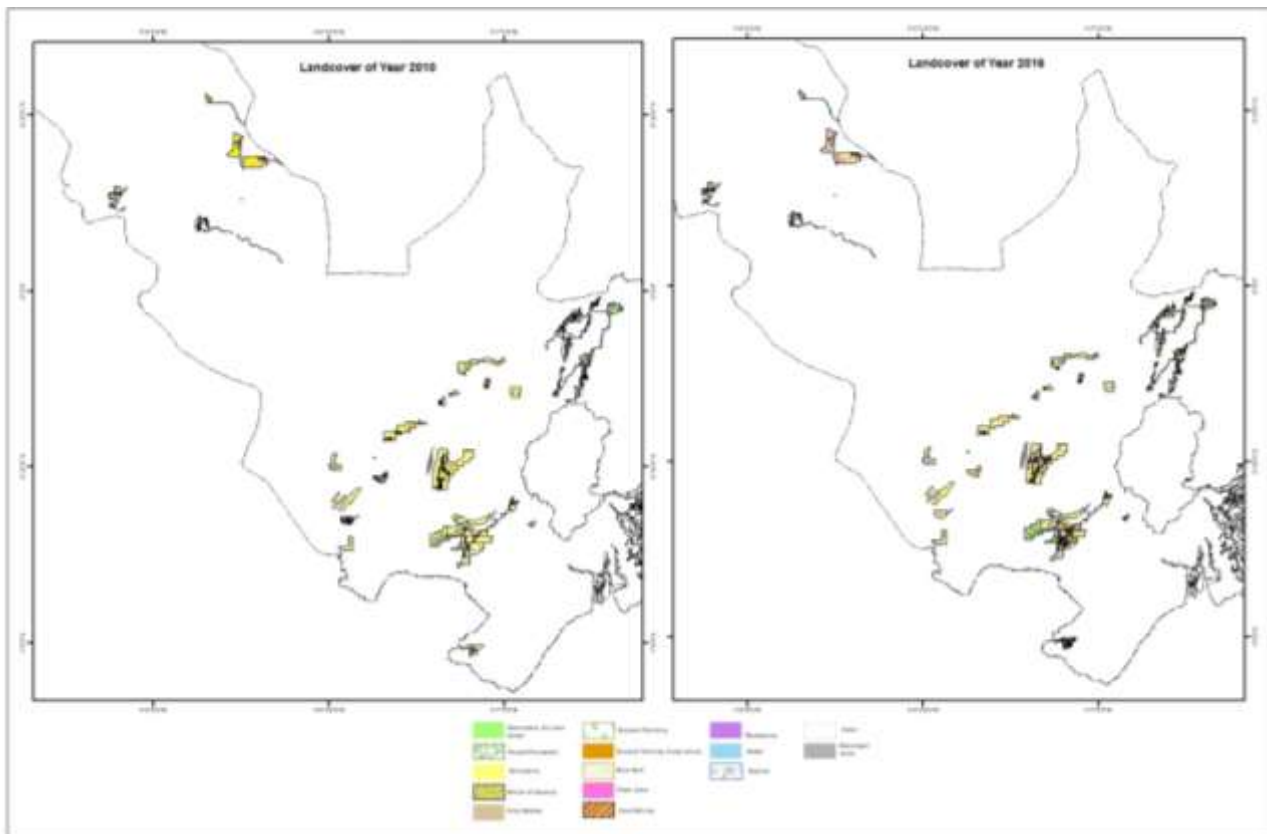


Figure 2 Landcover in the Concession of Coal Mining Area in the Forests of Kutai Kartanegara between 2010 and 2016.

Carbon Emission in the Forest Use for Coal Mining Concession Areas

Coal mine applies open-pit system and as the result, requires land clearing for its production activities. Land clearing for coal mine turns vegetated area into non-vegetated one or even vegetated area into water. Guan et al. (2017), finding that coal mining in the Xilingol meadows showed seven classes of land use, i.e.: open stope, stripping area, waste disposal area, mining industry area, agricultural land, urban area and grassland. The presence of surface coal mining disrupts the pasture ecosystems so the area fell by 8 661.15 Hm2 in 2005-2015. The mining operation area and its infrastructure increase.

It can affect carbon stock of the area above. Turning vegetated area into mine or no-vegetated area other than mine will decrease amount of carbon reserve. This will result in carbon emission. Agus et al. (2013) stated that mine does not have any carbon stock (zero carbon stock). Furthermore, Huang et al. (2014) stated that the vegetation located in the area near Xinzhouyao coal mine was disturbed, both its growth rate and its ability to absorb carbon, so the carbon stock in the area would decrease and its carbon emissions would increase.

Table 3 shows that, emission meant decreasing amount of carbon stock while absorption meant the carbon stock was increasing. The shrubs was the type of land in the concession area producing the highest carbon emission and the open area had the highest carbon absorption. CO₂ emission will be increased because no longer vegetation which absorb it. These vegetations role as Carbon-sink.

The shrubs produced carbon emission when they became open area or mines. According to Wright and Wimberly (2013) and Lark et al. (2015) in Ahlehring (2016), it is important to protect grasslands/shrublands from conversion because of its carbon stock has a high risk of loss to the atmosphere. Gunawan et al. (2017) stated that the carbon reserve was declining from 369 910 tons in 2010 to 310 640 tons in 2015 due to land conversion. The forests and shrubs turned into agricultural and residential areas.

Meanwhile, most of the land areas turned into shrubs and vegetated area and therefore, had high carbon absorption. In Adhikari and White (2016), shrubland can increase carbon sequestration. In this context, mining area had contribution towards carbon absorption because changing the mines into vegetated areas (forest plantation, shrubland, dry-land farming mixed shrubs, rice field and open area) increased the amount of carbon reserve.

Table 3 Carbon Absorption and Emission (C) of each Landcover.

No	Land Clearing	Absorption	Emission	Net emisi (C ton)
1	Secondary Dry Land Forest	-	3 869.73	3 869.73
2	Forest Plantation	(445.65)	121 272.70	120 827.05
3	Shrubland	(5 251.90)	152 402.76	147 150.86
4	Shrubland of Swamp	(5.94)	625.75	619.81
5	Crop Estate	-	322.51	322.51
6	Dry Land Farming	(16.20)	32.37	16.17
7	Dry Land Farming mixed Shrubs	(161.88)	1 572.93	1 411.04
8	Rice Field	(4 224.66)	173.09	(4 051.57)
9	Open Area	(51 368.05)	605.61	(50 762.45)
10	Mining	(48 019.74)	-	(48 019.74)
11	Residential Area	-	-	-
12	Water	(7 195.58)	-	(7 195.58)
13	Swamp	-	-	-
Total		(116 689.60)	280 877.43	164 187.83

Source: Data processing

Reclamation and revegetation turned the mines into forest resulting lower carbon absorption from the shrubs. In their study, Lutfi and Antono (2011) described that PT Gunung Bayan Pratama Coal produced 22 351 Tons/Hectare carbon stock in the reclamation area and 29 675 Tons/Hectare in the Base Line/secondary forest. Furthermore, Amichev et al. (2008) revealed that the rate of carbon sequestration in a mining area may be higher between before and after reclamation, depending on the quality of plant species used for post-mining planting in carbon sequestration.

In coal mines located in forest area, carbon emission is identified from its amount in both vegetated and non-vegetated areas. In which, its size was 48 037.79 ha, the total amount of carbon emission was 164 187.83 C tons or 0.60 Mton CO₂-eq.

CONCLUSION

There is changing landcover pattern taking place in the concession area, a contracted area in Kutai Kertanegara forest used for coal mines. Size of areas that consist of wet shrubs, crop estate, dry-land farming, dry-land farming and shrubs, open area, mining, residential areas and water is increasing while those that consist of secondary dry-land forest, forest plantation, shrubs, and rice fields are decreasing. The findings showed 12,663.38 hectares of the forest had been shifted into different landcover change. The amount of carbon emissions was 164,187.83 C tons or equal with 0.60 Mton CO₂-Eq.

Satellite imaging with very high resolution and field survey/observation are two data collection methods to get more accurate and trustworthy information.

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